CHAPTER

2

The Current Status of and Prospects for Distributed Generation

Distributed generation refers to the production of electricity at or near the place of consumption.[1] Examples of distributed generation include backup generators at hospitals, solar photovoltaic systems on residential rooftops, and combined heat and power (CHP) systems (also known as cogeneration) in industrial plants and on university campuses. Those applications differ from the infrastructure for supplying electricity that utilities in the United States have built over the past five decades. Under that infrastructure, utilities typically have built power plants away from centers of consumption, on the basis of such factors as fuel transportation costs and environmental regulations, and then moved that electricity long distances over high-voltage transmission lines to local distribution systems, which then reduce the voltage and deliver the power to retail consumers.

Although some types of distributed generators have been around for a long time (the earliest generators were largely "distributed" in the sense that they were located near the points of consumption), total customer-owned generation as a percentage of all output is small. The Energy Information Administration (EIA), an agency within the U.S. Department of Energy (DOE), estimates that in 2000 (the latest year for which data are available), only 0.5 percent of total U.S. electricity generation (21 billion of 3,800 billion kilowatt-hours) was from "non-utility generation for [customers'] own use." In addition, cogeneration systems in the commercial and industrial sectors produced 135 billion kilowatt-hours (3.6 percent of U.S. generation) for their own use.[2]

Three basic characteristics differentiate most distributed generation from traditional electricity supply: location, capacity, and grid connection. Distributed generators are located at or near the point at which the power is used. They are typically on-site generators, owned and operated by retail customers, that are used to meet a portion of the customers' demand or to provide backup service for customers that need highly reliable power. Applications of distributed generation could include combined heat and power operations—for example, a university could use CHP to generate electricity on campus and then use waste steam from the boiler to heat buildings.

Electric utilities can also install their own small generators near customers. Such installations relieve congestion in power lines during periods of peak demand, helping to defer investments in additional transmission and distribution capacity. They may also be used to boost the

1. Although there is no universally accepted definition of distributed generation, most of the policy issues surrounding distributed generation concern small customer-owned units that are connected to the grid at the distribution level and that primarily serve on-site needs. In this report, that is how the term is used, except when utility-owned applications are being discussed.

2. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2003, with Projections to 2025,* DOE/EIA-0383(2003) (December 2002), Table A8. "Combined heat and power plants whose primary purpose is to sell electricity, or electricity and heat, to the public (NAICS [North American Industrial Classification System] code 22)" produced an additional 4.2 percent.

quality and reliability of local electricity service by providing voltage control and backup power to customers who require such "premium" service.

The second defining characteristic of most distributed generation is its size. Generation capacities of customer-owned units, used primarily to meet on-site requirements, typically range from a few kilowatts to several hundred kilowatts. Generators in that range are typically best suited to applications that meet the energy demands of individual homes and businesses or of small groups of customers. Very few customers require generators larger than 1 megawatt to serve only their on-site needs.[3]

The level of their connection with the local or regional electric grid is the third characteristic that distinguishes distributed generators from traditional suppliers. Traditional suppliers are connected to the grid at the transmission level (the high-voltage portion of the delivery network). If distributed generation came into widespread use, most distributed generators would be connected to the grid at the distribution level, which is the portion of the delivery network, built with limited capacity, that transports electricity at low voltages for the final few miles to the customer. (That is also the portion of the network that is owned and operated by local retail utilities, most of which are regulated by state agencies.)

Most of the policy debate surrounding distributed generation concerns small (less than 2 megawatts) customer-owned systems that primarily serve on-site loads and are connected to the utility network at the distribution level. The debate has arisen in part because of technical issues surrounding distribution-level connections to the grid and possible conflicts between local utilities and generators that are both producers of electricity and retail utility customers. Both of those matters are discussed in Chapter 4.

3. Most cogeneration (combined heat and power) applications are considered distributed generation because they typically are located on a customer's premises and serve on-site electricity and thermal needs. On the basis of those criteria, cogenerators account for almost all existing distributed generation production. But those plants are mostly large generators (at least 50 megawatts), often owned by third parties, that earn significant revenues by selling most of their output to utilities.

How Distributed Generation Contributes to the Nation's Power Supply

The applications that account for the largest portion of the customer-owned power production by distributed generation in the United States are cogenerators used in industrial or commercial operations or primarily to generate electricity for sale. Those cogenerators typically range in size from 1 to 500 megawatts, and they are capable of producing enough electricity to serve 500 to 25,000 households. According to the EIA, slightly more than 27,000 megawatts of cogeneration capacity existed in the commercial and industrial sectors in 2000.[4] That is 3.4 percent of the total regularly operated generating capacity in the country. Most cogeneration is accounted for by systems of more than 50 megawatts, concentrated in such industries as paper products, chemicals, and petroleum refining.[5]

After cogeneration, backup units that are operated only in emergencies account for the most distributed generation capacity. Backup generators used by such businesses as hospitals and large commercial buildings typically range in size from a few to several hundred kilowatts. According to a 1995 survey by the EIA, nearly one-fourth of the commercial floor space in the country had some capacity to generate electricity on-site.[6] But less than 1 percent of that capacity was ever used to generate electricity to meet peak demand or to operate continuously; in essence, it constitutes a large reservoir of capacity that is virtually untapped as a regular source of power. The Gas Research Institute has estimated that up to 40,000 megawatts of backup generation capacity exist in the United States, compared with a total of 808,000 megawatts of regularly

4. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2003*, Table A9. There are another 27,400 megawatts of cogeneration capacity in the utility sector.

5. Department of Energy, Energy Information Administration, *The Market and Technical Potential for Combined Heat and Power in the Industrial Sector* (prepared by Onsite Sycom Energy Corporation, January 2000), p. 17.

6. Department of Energy, Energy Information Administration, *Modeling Distributed Electricity Generation in the NEMS Buildings Models* (August 2000), which is available at www.eia.doe.gov/oiaf/analysispaper/electricity_generation.html.

operated electricity generating capacity.[7] Available state-level data show a similar relationship. The California Energy Commission (CEC) has compiled an inventory of backup generators that individually have at least 300 kilowatts of capacity.[8] It found more than 4,000 such generators in the state in 2001, with a total capacity of 3,200 megawatts. Those generators could, if available, boost the state's total installed capacity of 54,000 megawatts by more than 5 percent, the CEC estimated. Those data suggest that gross available capacity in the United States could be increased by 5 percent to 10 percent if all emergency backup generators were adapted to operate regularly.

Looking to the future, the EIA projects that additions of electricity generating capacity between 2000 and 2025 will total almost 450,000 megawatts.[9] According to the EIA's Reference Case Mid-Term Energy Forecast, more than 11 percent of that capacity will come from distributed generation (defined here as the additions of cumulative capacity in the nonutility sectors plus electric power sector cogeneration and natural gas distributed generation).[10] The electric power sector will add another 3 percent of the total in the form of renewable energy sources (biomass, municipal solid waste, and solar photovoltaic), most of which would be distributed generation. The EIA reference case forecast implicitly assumes no major changes in legislation or regulations that would encourage increased reliance on distributed generation.

But there are reasons to expect that distributed generation could meet a significantly greater portion of future electricity demand in the United States, at costs that could compete with those of generation from new central power plants. The first reason is the existence of the considerable amount of backup generation capacity (discussed above) that is not included in the EIA's estimates of existing or projected capacity. Backup capacity represents a sunk cost to its owners, who have typically installed the generators to meet reliability needs or building code requirements. In the absence of environmental prohibitions or other restrictions, many of those generators could be adapted to operate regularly, at the cost of modest investments in improved electronic power controls and pollution control equipment.

Studies commissioned by DOE on the market and technical potential for combined heat and power in the commercial and industrial sectors identify another reason.[11] The studies found 163,000 megawatts of remaining CHP potential in the commercial and industrial sectors combined, in addition to more than 49,000 megawatts of currently installed CHP (*see Table 1*). That potential is spread across all major commercial building types and industrial activities, with concentrations in paper products, schools, and office buildings. The EIA reference case forecast projects that only 20 percent of that potential will be realized in the next two decades. Policy changes that encouraged distributed generation could increase that percentage significantly.

A Description of Selected Electricity Generation Technologies

Several technologies are frequently mentioned as well suited to small and medium-sized distributed generation applications. Among the technologies fueled by fossil energy are conventional steam turbines, combustion turbines, internal combustion engine generators, microturbines, and fuel cells. The renewable technologies are

7. Anne-Marie Borbely and Jan F. Kreider, eds., *Distributed Generation: The Power Paradigm for the New Millennium* (Boca Raton, Fla.: CRC Press, 2001), p. 65.

8. California Energy Commission, *Database of Public Back-Up Generators (BUGS) in California,* available at www.energy.ca.gov/database.

9. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2003.*

10. EIA's forecast breaks out distributed generation in the electric power sector as a separate technology. It defines distributed generation as "primarily peak load capacity fueled by natural gas."

11. Department of Energy, Energy Information Administration, *The Market and Technical Potential for Combined Heat and Power in the Commercial/Institutional Sector* and *The Market and Technical Potential for Combined Heat and Power in the Industrial Sector* (both prepared by Onsite Sycom Energy Corporation, January 2000). Those studies defined the technical market potential as "an estimation of the market size constrained only by technological limits—the ability of combined heat and power technologies to fit existing customer energy needs." (See p. 9 of the commercial/institutional sector report.)

Table 1.

Installed and Potential Combined Heat and Power Generation

(In megawatts)

	Installed	Remaining Potential	Total
Industrial	44,242	88,341	132,583
Commercial	4,926	74,638	79,564
Total	**49,168**	**162,979**	**212,147**

Source: Congressional Budget Office based on Department of Energy, Energy Information Administration, *The Market and Technical Potential for Combined Heat and Power in the Commercial/Institutional Sector* and *The Market and Technical Potential for Combined Heat and Power in the Industrial Sector* (both prepared by Onsite Sycom Energy Corporation, January 2000).

photovoltaic cells, wind-powered generators, and biomass-fueled generators.

Conventional steam turbines and combustion turbines are well-developed technologies that are widely used for medium-sized and large power systems (more than 500 kilowatts). In very large systems, typically built by commercial generators, combustion turbines are often operated in tandem with steam turbines that use waste heat from the combustion turbine to fire a boiler (that combination is referred to as a combined-cycle system). Conventional combustion turbines produce low emissions, given standard control equipment, and they have low maintenance and operating costs relative to those of most other generating technologies. Those characteristics, along with the short lead times needed to build units, make them the preferred technology for most conventional generation applications requiring more than several megawatts of power. Such large units are used by industrial plants in combined heat and power configurations that generate excess power for sale to utilities.

Internal combustion engine generators, including diesel cycle and spark ignition motors, are the most commonly used technology providing backup power for reliability or emergency-supply purposes. Units range in size from 5 kilowatts to 7 megawatts. They can burn refined petroleum products (diesel and gasoline) or natural gas. Models that burn natural gas have very low emissions because of improved design of the combustion process and their use of catalytic converters. The costs per installed kilowatt for units with capacities suitable for distributed generation are among the lowest of all the mature technologies.

Microturbines are small combustion-turbine generators that were developed on the basis of the turbocharger technology used in trucks and airplanes. The capacity range of microturbines (30 kilowatts to 400 kilowatts) covers the average load requirements (consumption needs) of most commercial and light industrial customers. Microturbines have low emissions of pollutants, especially nitrogen oxides, which would permit their installation in urban areas with restrictive emissions standards. Microturbine electricity generators are in the early stages of commercial development; studies commissioned by DOE predict that their installed equipment costs (costs of equipment plus installation) will fall significantly in the future.[12]

Fuel cells use an advanced electrochemical process to generate electricity. The process is comparable to that used in conventional batteries, except that the reactant material in fuel cells can be replenished so that the units will not run down. Fuel cells produce virtually no emissions of air pollutants or greenhouse gases. Because their costs per installed kilowatt are still high relative to those of conventional technologies, commercially available fuel cells currently suit only very specialized applications. But some companies have developed new fuel cell technologies that they project will lower costs significantly.[13]

12. See, for example, Department of Energy, National Renewable Energy Laboratory, *Gas Fired Distributed Generation Technology Characterizations: Microturbines* (prepared by Energy and Environmental Analysis, November 30, 2002), which projects declines of 50 percent or more in installed capital costs by 2030.

13. For example, the California Distributed Energy Resource Guide (a Web site on distributed energy run by the California Energy

Photovoltaic cells convert sunlight directly into an electric current. A panel of semiconductor material sandwiched between two conducting layers absorbs solar energy and releases electrons to produce the current. Photovoltaic systems can be small, which is why they are widely used in residential settings, particularly in the Southwest and California. Because photovoltaic systems, by their nature, produce electricity intermittently, they require battery storage or a supplemental power source to provide continuous electricity service. Photovoltaic cells produce no direct emissions, and they have low maintenance requirements. Improvements in manufacturing processes have reduced the costs of photovoltaic systems significantly in the past decade. But their acquisition and installation costs, per kilowatt, are still almost an order of magnitude (10 times) greater than those of conventional systems, and their costs per kilowatt-hour of delivered electricity are three to four times the current average price of electricity in the United States.

Wind generators are turbines powered by windmills. A mature technology, wind turbines have been widely used in California and Europe by utilities and independent power producers to generate electricity to be sold over the grid. In California, wind farms have total generating capacities ranging from 15 megawatts to more than 600 megawatts (individual turbines at those sites have capacities of more than 1 megawatt). Most analysts would not consider large wind turbines to be a type of distributed generation because they are not typically located near customers. (Advocates of commercial wind power share many of the same policy concerns as advocates of distributed generation, however.) As with photovoltaic cells, the potential of wind generators is limited by available wind resources and by issues related to the siting of these large towers with their rotating wind blades (including noise and threats to migrating birds).

Small wind turbines designed for residential and rural applications to date account for only a limited share of the market. For residential and small commercial distributed generation applications, suitable wind turbine capacities are 5 kilowatts to 50 kilowatts. The installed costs per kilowatt for those smaller systems are much higher than for the large systems. Because of the large amount of space they require, small wind generators are generally appropriate for applications in rural areas with good wind resources.

Biomass refers to a renewable fuel rather than to a particular technology. The EIA defines biomass as "organic nonfossil material of biological origin constituting a renewable energy source." Wood products, animal and plant agricultural waste, and municipal solid waste are all examples of biomass. Electric generators use biomass as fuel, often mixed with other fossil fuels. The most common use of biomass is to heat a conventional boiler directly. Another possible application is biomass gasification, in which the product would be used in place of natural gas. Although biomass may provide environmental benefits by displacing coal-fired generation, the burning of biomass and the production of animal wastes (as two examples) can create air and water quality problems of their own. The financial attractiveness of biomass depends on such factors as the availability and cost of the organic material, the avoided cost of alternative disposal of the material, and the need for residual heat to warrant cogeneration.[14]

The Cost Structure of Distributed Generation

The direct costs of distributed generation to customers include the installed cost of the equipment, fuel costs, nonfuel operation and maintenance (O&M) expenses, and certain costs that the customers' utility imposes. The cost estimates that follow have been compiled from authoritative sources, but they must be considered as indicative of the relative magnitudes of costs across technologies rather than as point estimates. The values of each

Commission) states that most manufacturers, once the cells can be produced in volume, are aiming for fuel cell capital costs below $1,500 per kilowatt; see www.energy.ca.gov/distgen for more information.

14. Because of the wide range of ways in which biomass fuels could be used in distributed generation, this paper omits cost estimates for "typical" biomass applications. Most of the barriers and policy issues that apply to other distributed generation technologies, however, especially those relating to environmental and siting requirements, also apply to biomass.

cost's components may vary substantially from one application to another, on the basis of several factors, some of which are discussed below. The contribution of utility charges to the total costs of generation are not included in the estimates (they are discussed in Chapter 4, which describes barriers to adoption).

To make this comparison of costs most useful, the Congressional Budget Office (CBO) assumed for each technology an installed capacity, a rate of utilization, and (in some cases) a geographic location that would be suitable for serving the electricity needs of individual customers. For example, the costs for the wind turbine discussed here are for a size that might be used in a small rural business (such as a farm) in a location with favorable wind resources. On that basis, data compiled from various industry and government sources describe the current costs of the most common types of electricity generation technologies (*see Table 2*). Data for a combined-cycle unit are presented as well; as the largest source of additional electricity from utilities and independent power producers, combined-cycle systems provide a representative benchmark against which the costs of other technologies can be measured.

Capital Costs

The costs of acquiring and installing a generating unit vary widely, depending on technology, capacity, and other factors. The Department of Energy estimates that the typical installed capital costs for distributed generators range from under $1,000 per kilowatt for a combustion turbine to almost $7,000 per kilowatt for a solar photovoltaic system.[15] Among small-capacity technologies, internal combustion engines (fueled by diesel and gasoline) have the lowest capital costs and highest operating costs. Renewable technologies (using wind and solar power) have the highest capital costs and lowest operating costs. New high-efficiency technologies (microturbines and fuel cells) fall in between.

For customers who maintain emergency backup generation on-site, the relevant capital cost for choosing the least expensive source of electricity is not the total cost but rather the additional investment needed to operate an on-site generator at the same time they are connected to the utility network (termed parallel operation). (Currently, many institutions and office buildings that are required to have backup generators are permitted to operate those generators only when they are disconnected from their utility network.) That extra investment may include such costs as equipment upgrades to meet environmental requirements for regular operation and additions of power controls and metering to permit parallel operation. Those additional costs would typically be small relative to the basic investment costs—especially for installations in new buildings, as opposed to retrofit upgrades.

Long-Run Costs of Production

Although consideration of a technology's capital costs can be important when choosing to invest in distributed generation, estimates of what economists refer to as long-run average costs—costs per unit of output that reflect capital and operating expenses—are generally the more important for investment decisions. Perhaps more relevant for comparing distributed generation technologies with one another and with utility costs and residential prices is a commonly used index of long-run costs known as the "levelized" cost. Levelized cost is a summary measure of the average cost of electricity per kilowatt-hour, expressed in current dollars. It is defined as the net present value of all direct costs (for capital, fuel, and O&M) over the expected lifetime of the system, divided by the system's total lifetime output of electricity.[16]

A key input to those calculations is the assumption about capacity utilization (the percentage of time that the unit typically operates) for each technology. For purposes of these comparisons, CBO's estimates assume that all fossil-fueled systems will be operated 90 percent of the time

15. Department of Energy, Office of Energy Efficiency and Renewable Energy, and Electric Power Research Institute, *Renewable Energy Technology Characterizations,* EPRI-TR-109496 (December 1997); and Department of Energy, Energy Information Administration, *The Market and Technical Potential for Combined Heat and Power in the Commercial/Institutional Sector.*

16. The output stream is discounted at the same rate as the costs, to keep the two comparable. The present value is a single number that expresses a flow of current and future income (or payments) in terms of an equivalent lump sum received (or paid) today.

Table 2.

Comparison of Selected Electricity Generation Technologies

	Capacity (kW)	Capital Cost[a] ($/kW)	Fuel Cost ($/kWh)	O&M Cost ($/kWh)	Service Life (Years)	Heat Rate[b] (Btu/kWh)
Microturbine—Power Only	100	1,485	0.075	0.015	12.5	13,127
Microturbine—CHP	100	1,765	0.035	0.015	12.5	6,166
Gas ICE—Power Only	100	1,030	0.067	0.018	12.5	11,780
Gas ICE—CHP	100	1,491	0.027	0.018	12.5	4,717
Fuel Cell—CHP	200	3,674	0.029	0.010	12.5	5,106
Solar Photovoltaic	100	6,675	0	0.005	20	n.a.
Small Wind Turbine	10	3,866	0	0.005	20	n.a.
Large Wind Turbine	1,000	1,500	0	0.005	20	n.a.
Combustion Turbine—Power Only	10,000	715	0.067	0.006	20	11,765
Combustion Turbine—CHP	10,000	921	0.032	0.006	20	5,562
Combined-Cycle System[c]	100,000	690	0.032	0.006	20	5,642

Source: Congressional Budget Office based on data from the Department of Energy's National Renewable Energy Laboratory and Energy Information Administration; Bergey Windpower Company; and the California Energy Commission.

Notes: kW = kilowatt; kWh = kilowatt-hour; O&M = operation and maintenance; Btu = British thermal unit; CHP = combined heat and power (also known as cogeneration); ICE = internal combustion engine; n.a. = not applicable.

All costs are in 2000 dollars. Fuel costs were calculated on the basis of national average prices for natural gas delivered to commercial customers in 2000.

a. The cost of acquiring and installing the generating unit. It does not include effects of tax credits or other direct subsidies for specific technologies.

b. High heat value.

c. In a combined-cycle system, a combustion turbine is operated in tandem with a steam turbine.

(termed "base load" operation), whereas wind and photovoltaic systems will run 40 percent and 27 percent of the time, respectively. The rates for wind and solar power are consistent with conditions favorable for their use.[17] No tax credits or other subsidies are included in the calculations for any technology or fuel source.

The costs per kilowatt-hour of power for most electricity generation technologies are at least 70 percent greater than those for a combined-cycle plant (*see Figure 1*). The single exception to that comparison is the combustion-turbine technology in a CHP configuration (its costs are only 5 percent greater), which would be used only by large customers with significant steam or hot water requirements. Although the comparisons do not take into account transmission and distribution costs for utility-supplied power, those would typically add 25 percent to 50 percent. The costs of power from distributed generation would be higher still.

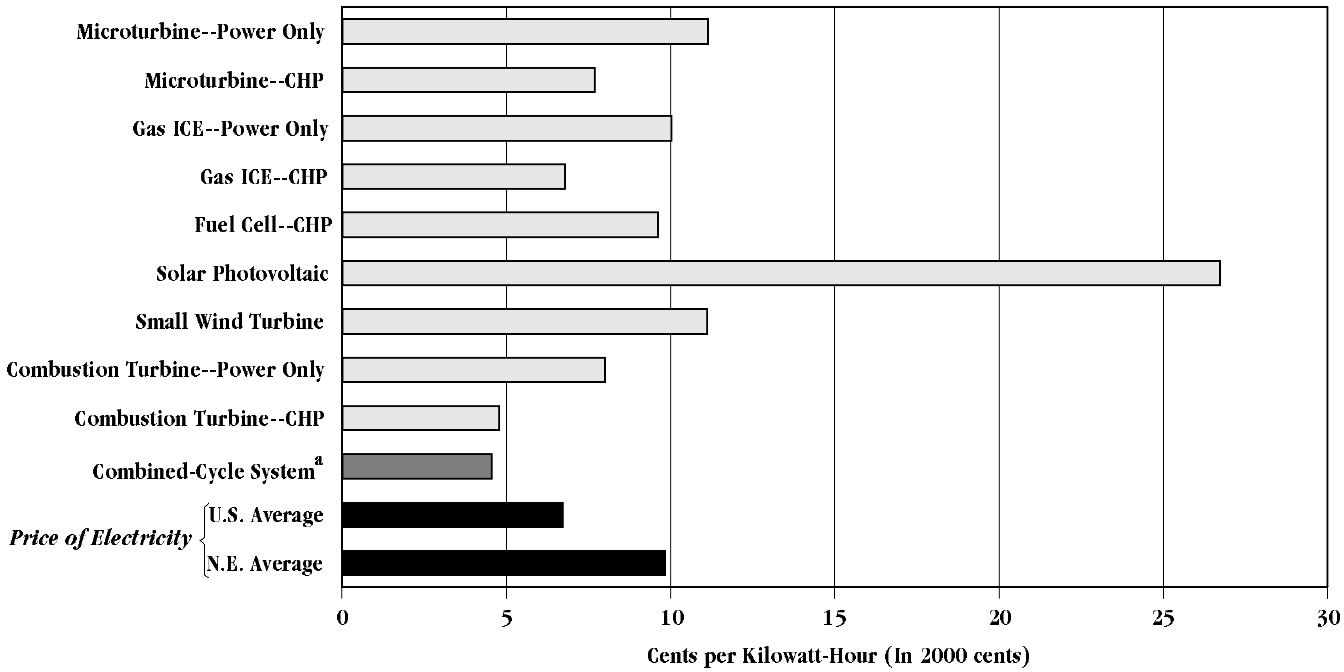
The most cost-competitive distributed generation technologies are fossil-fuel engines—diesel motors (internal combustion engines) and microturbines—in combined heat and power configurations. The fuel costs of producing the electricity for those systems, as for all CHP technologies, are net of the fuel costs of producing the steam or hot water alone. That calculation implicitly assumes that the customer can use the steam or hot water productively and will incur the cost of producing it even without the combined heat and power system.

Aside from the CHP systems and both kinds of large combustion turbines, other distributed generation tech-

17. For the wind technology, a usage rate of 40 percent is the high end of the range of capacity factors cited by the California Energy Commission in its California Distributed Energy Resource Guide, which is available at www.energy.ca.gov/distgen/equipment/wind/performance.html. For the solar photovoltaic technology, a usage rate of 27 percent corresponds to locations where a one-kilowatt array can produce 6.5 kilowatt-hours per day, on average. In the United States, these are places with the highest levels of sun exposure, such as Phoenix, Arizona, and Albuquerque, New Mexico.

Figure 1.

Levelized Cost of Selected Technologies Suitable for Distributed Generation



Source: Congressional Budget Office using data on electricity prices from Department of Energy, Energy Information Administration, *Electric Power Annual 2000* (August 2001), Table 21.

Notes: CHP = combined heat and power (also known as cogeneration); ICE = internal combustion engine; N.E. = New England.

The levelized cost is the average cost of electricity (cents per kilowatt-hour) over the operating life of the generation equipment. Future costs and output flows are based on data in Table 2 and are discounted at 7 percent from their present values. The cost estimates assume that the systems powered by fossil fuels will be operated 90 percent of the time and that the wind and solar photovoltaic systems will run 40 percent and 27 percent of the time, respectively. Levelized cost comparisons do not include the effects of tax credits or other direct subsidies for specific technologies.

"Large wind turbine" is not included in the figure (as it is in Table 2) because it is not generally considered to be well-suited to distributed generation applications (typically, it is not located near customers).

a. In a combined-cycle system, a combustion turbine is operated in tandem with a steam turbine. The system is included here as a benchmark for the cost of power from new large-scale generators. Transmission and distribution expenses would add an estimated 2.4 cents per kilowatt-hour, on average, to the marginal cost of delivered power.

nologies have electricity costs that are more than twice those of the combined-cycle technology. The combustion turbines, which utilities themselves often use to meet certain new consumption needs (loads), would be suitable only for large commercial or industrial customers. Among the remaining technologies, conventional engines (those marked "power only" in Figure 1) are the closest in cost to the combined-cycle technology. But they are still at least 120 percent more expensive than power from new utility plants. Advanced high-efficiency technologies (microturbines and fuel cells) and renewable technologies (small wind and solar photovoltaic) are even more expensive.

Nonetheless, the costs of some distributed generation technologies, especially those in combined heat and power systems, are below the retail price of utility-supplied electricity in many parts of the United States. For example, the average price of electricity for all sectors in New England in 2000 was 9.8 cents per kilowatt-hour. In the same year, the average price of electricity in the commercial sector in the United States was 7.2 cents per kilowatt-hour. The estimated cost per kilowatt-hour for a CHP internal combustion engine system (7.1 cents) was lower than both prices.

The average price of electricity in the United States greatly exceeds the cost of power from new generation for at least two reasons. First, the average price includes the costs of transmission and distribution, which add approximately 25 percent to 50 percent to the delivered cost of power. Second, the prices charged by most regulated utilities are set to recover their past investments, whose costs—especially those for generation—exceed the current costs of new plants.

That comparison may explain much about the contrasting incentives of utilities and customers to invest in distributed generation. Regulated utilities are concerned about retaining their sales base in order to recover the costs of past investments. Customers are concerned about lowering their electricity costs without sacrificing the reliability of their utility service connection.

Trends in Costs

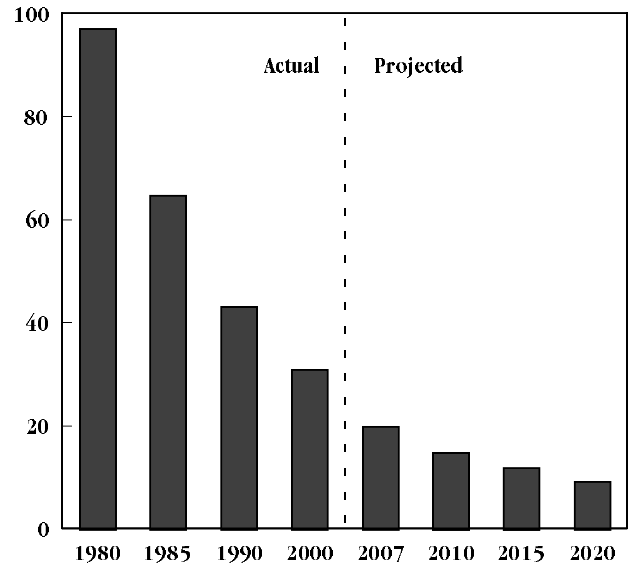
The capital and operating costs of certain distributed generation technologies have fallen significantly in recent years and can be expected to continue to do so. In the case of one technology, photovoltaic systems, the cost per delivered kilowatt-hour in suitable applications has plummeted by almost 70 percent since 1980, and it is projected to decline by another 70 percent from current levels by 2020 (*see Figure 2*).[18]

Similarly, developers forecast that fuel cells will improve in performance and decline in cost over the next several years to the point that they will soon be suitable for widespread use in distributed generation. A recent study by Lawrence Berkeley National Laboratory projected that the installed cost per kilowatt for a 200-kilowatt fuel cell would drop from $3,500 in 2000 to $1,300 (in 2000 dollars) by 2010.[19] That projection, and similar ones from other sources, are based on "target forecasts for installed costs from developers of [advanced technology] solid oxide and molten carbonate fuel cell systems."[20]

Figure 2.

Levelized Cost of Solar Photovoltaic Electricity, 1980 to 2020

(Cents per kilowatt-hour)



Source: Congressional Budget Office based on data from Department of Energy, Office of Energy Efficiency and Renewable Energy, and Electric Power Research Institute, *Renewable Energy Technology Characterizations*, EPRI-TR-109496 (December 1997).

Whether the direct costs of distributed generation will continue to fall relative to the costs of utility-supplied power is another matter. Electricity prices have generally dropped as a result of competition—although California's experience of high prices and rolling blackouts in 2000 and 2001 is a notable exception—and are likely to benefit from further market restructuring in coming years. Technical improvements in large-capacity generation technologies used by utilities are also likely to lower the costs of supplying power. The EIA projects in its reference case forecast, however, that the average price of electricity in the United States will remain virtually constant over the next two decades, indicating at least in that case that neither competition nor cost-saving technical change is

18. Department of Energy, Office of Energy Efficiency and Renewable Energy, and Electric Power Research Institute, *Renewable Energy Technology Characterizations*.

19. Consortium for Electric Reliability Technology Solutions, *Modeling of Customer Adoption of Distributed Energy Resources*, LBNL-49582 (August 2001), Tables 1 and 2.

20. Department of Energy, Energy Information Administration, *The Market and Technical Potential for Combined Heat and Power in the Commercial/Institutional Sector*, p. 24.

likely to have much effect on the economics of utility-supplied power.

Other Economic Considerations in Installing Distributed Generators

Although a comparison of typical costs for various distributed generation technologies can be useful, it tends to obscure several important facts. Distributed power can differ qualitatively from central power or can save money in other ways, and that value may outweigh any direct cost difference. Moreover, certain distributed generation technologies or energy sources can benefit from existing federal and state incentives (including investment tax credits or mandates on utilities to purchase power generated from renewable sources).

The significance of those quality and cost advantages is demonstrated by the fact that distributed generation applications are already widely available in several niche markets. Commercial and small industrial customers with significant hot-water needs can use microturbines in combined heat and power configurations. Customers who have on-site emergency backup generators may be able to run them regularly during periods of peak demand, when wholesale prices are high. Customers in environmentally sensitive areas can use fuel cells that produce extremely low emissions and no noise. Photovoltaic systems and wind turbines can be used in rural applications, reducing the need for capital spending to extend power lines to remote sites.

Distributed generation can also protect against service interruptions or variations in voltage or frequency that can harm equipment. The majority of those interruptions are due to equipment failures or power line breaks close to customers' premises. The value of improved reliability is difficult to quantify; it depends largely on the reliability of the regular electricity supply.[21] Local building ordinances and safety concerns dictate most of the backup power needs in the nation—for example, for hospitals and high-rise buildings. But the value of backup capability would also be great wherever a manufacturing process depended on the continuous operation of power-sensitive equipment, such as in the production of computer chips. Generally, those backup units would be available to operate whenever interruptions occurred in utility-supplied power. During California's recent electricity crisis, many businesses in that state purchased (or rented) diesel units just to ensure continuity of operations.

Besides possibly saving on their own electricity costs (as output from distributed generators displaced utility-supplied power provided at retail rates), some owners of distributed generators might be able to earn money by selling their excess power to the utilities. Federal law requires utilities to purchase power from cogeneration facilities and generators powered by renewable fuels at prices reflecting the utility's own long-run marginal costs of supply. And many states require utilities to give credit at retail rates for excess power from certain small distributed generators (termed net metering). But those requirements are often limited to generators that use renewable fuels or high-efficiency technologies. Initiatives to broaden the sale of excess power by operators of distributed generators to regional wholesale spot markets at prices that varied hourly (real-time pricing) could benefit the operators while increasing the available power supply.

Businesses and households that are considering investing in distributed power may also benefit from other programs that the federal government and many states have developed. At the federal level, the Energy Policy Act of 1992 provides tax credits for certain investments in solar, wind, and biomass-fueled electricity generation. At the state level, renewable portfolio standards mandate that a certain percentage of electricity generation come from renewable energy sources. Several states, including New York and California, have adopted such renewable portfolio requirements. Many states also offer tax credits for investment in certain renewable technologies. For example, the 10 percent corporate tax credit for investment in solar, wind, and biomass technologies that is offered in Texas is typical.[22]

21. Service quality refers to the stability of the voltage and frequency at which electricity is delivered. Reliability refers to the frequency and duration of service interruptions.

22. See the Database of State Incentives for Renewable Energy's Web site (www.dsireusa.org/dsire/), funded by DOE's Office of Power Technologies, for a complete summary of federal, state, local, and utility programs that promote renewable energy.